Digital Image Processing of Remote Sensing Data in Malaysia

Mazlan Hashim, Ab.Latif Ibrahim and Muhammad Zulkarnain Abd. Rahman
Department of Remote Sensing
Faculty of Geoinformation Science and Engineering
Universiti Teknologi Malaysia
83100 Skudai, Johor

Abstract

Remote sensing systems now allow image been captured at ranges of electromagnetic spectrum beyond the range of photography. The development of active remote sensing systems, which enable it to function in all weather conditions, had shown a more promising development in the application of this technology. Digital image processing and image enhancement techniques provide recognition of contrasts among features of interests at orders of magnitude better than human eye. Looking at the current global scenario, operational application of remote sensing technology is becoming a common practice and well accepted at operational level in assisting decision making process in the natural resource management, environmental, conservation program and strategic planning. Remote sensing images (and information extracted from such images) are now beginning to be used extensively to locate specific features and conditions of the earth surface. The main objective of this paper is to highlight work on digital image processing in Malaysia as a whole, and also to highlight some of the work that have been carried out at the Department of Remote Sensing, Universiti Teknologi Malaysia. As digital image processing involved various procedures that may be quite complicated, the first part of this paper provide a brief description on the general term of digital image processing, while the focus of the second part of this paper digital image processing work that have been cariied out in Malaysia and also at Universiti Teknologi Malaysia

1. Introduction

Digital image processing has been the fundamental task in information extraction for wide applications of remote sensing technology. Such data processing involves all stages, starting from data acquisition, restoration (or pre-processing), and all data processing related to features or information extractions. The main objective of digital image processing in remote sensing is mainly in the extraction of information for mapping and monitoring Earth's resources, environmental management and strategic planning. The wide applications of remote sensing data have catalyst the wide availability of COTS (commercially-off-the-shelf system), hosted on various computing platforms depending on the complexity of the processing tasks to be undertaken. In recent years, trends in the digital image processing COTS is integrated with spatial analysis capability.

Although COTS digital image processing are adequate to be used in the extraction of information, but for operational purposes, the techniques and related algorithms used need to be customized for local scene's biophysical and biochemical parameters so as the information extracted is representing the real world. Customizations of these techniques and its related algorithms can be carried out within most COTS with embedded object-based programming tool. However, this is not self-achievable in most users' agencies in Malaysia due to various factors attributed to the level of expertise. This paper highlights the status of digital image processing of remote sensing data in Malaysia as a whole and also some examples of image processing works at the Department of Remote Sensing, UTM.

2. General Term of Digital Image Processing

Remote sensing data can only be very useful when meaningful information from the imagery can be extracted. This process of information extraction from remote sensing data involves the manipulation and interpretation of digital data, with an aid of a computer system. This form of image processing technique began in the 1960s. However, the related works at this stage are only limited to the process of analyzing airborne multi-spectral scanner data and digitized aerial photograph. After the launched of Landsat-1 in 1972, most remote sensing data are available in digital format, therefore all image interpretation and analysis involves some element of digital processing.

Numerous procedures such as formatting and correcting of the data, digital enhancement and classification of targets and features are involved in digital image processing. All these procedures are possible with the help of appropriate hardware and software system. Digital image processing normally involves a number of procedures that may be very complicated. However, with the availability and the advancement of computer system, the central idea behind image processing is quite simple. The digital image is fed into a computer one pixel at a time. The computer is program to insert these data into an equation, or a series of equations and then store the results of the computation for each pixel. These results form a new digital image that can be displayed or recorded in pictorial format or may itself be further manipulated by additional program.

2.1 Hardware and Software for Image Processing

A digital image processing system consists of computer hardware and image processing software, which are necessary to analyze digital image data as summarized below;

1). Central Processing Unit	Host computer (either on mainframe, workstation or PC), which resides operating system and applications software, random access memory (RAM).
2). System Input	Data input system such as CD/DVD reader, etc.
3). System Storage	Mass Storage (hard disk, CD, DVD).
4). Image Display System	CRT screen display system with appropriate image processing memory (Graphics card) to enable high

	resolution image display.
5). Application Software	All functions for processing digital image and related Arithmetic Co-processor
6). System Output	Production of hardcopies of processed images or reports.

The software for digital image processing system for remote sensing on the other hand, are typically comprised of the generic processing functions as summarised in figure 1.0.

Digital Image Processing

Preprocessing

1. Radiometric correction (of error introduced by sensor system and environmental effects
2. Geometric correction (image to map or image to image)

Display and Enhancement

3. Black and White , colour-composite display
4. Density slice
5. Magnification, reduction, roam, pan
6. Transets
7. Contrast manipulation
8. Image algebra (band ratioing, image differencing, etc)
9. Spatial filtering
10. Edge enhancements
11. Principal components
12. Linear combinations (e.g., kauth transform)
13. Texture transforms
14. Frequency transformations (fourier, cosine, Hadammard, Walsh etc.)
15. Digital elevation models (DEMs)
16. Three-dimensional transformations
17. Animation
18. Image compression

Information extraction

19. Supervised classification
20. Unsupervised classification
21. Contextual classification
22. Incorporation of ancillary data during classification
23. Radar image processing
24. Hyperspectral data analysis
25. Softcopy photogrametry to extract digital elevation model
26. Softcopy photogrametry to extract othophotographic
27. Expert system and/or neural network analysis

Image Lineage

28. Complete image or GIS file history

Image and map cartographic Composition

29. Scale postcript level 11 output of images and analysis

Geographic information Systems (GIS)

30. Raster (image) based GIS
31. Vector (polygon) based GIS must allow polygon comparison

Integrated Image Processing and GIS

32. Complete image processing system (Function 1 through 23)
33. Complete Image Processing system an GIS (Function 1 through 33)

Utilities

34. Network, (internet, local talk, etc.)

Every function listed might now be performed on personal computer digital image processing systems, as well as on workstations and mainframe computers.

There are some limitations found in most image processing systems. Examples of some of the limitations are;

1. Most system can generate a three-dimensional perspective view of the terrain, but only a few systems can perform soft copy analytical photogrammetric operations on overlapping imagery displayed on CRT screen and generate digital orthophotographs.
2. Only few systems can process remote sensor data with a large number of bands, that is, hysperspectral data.
3. Most digital image processing systems do not interface well with expert systems or neural networks.
4. The image lineage information is indispensable when the products derived from analysis of remotely sensed data are subjected to intense scrutiny as in environmental litigation.

The following factors should be considered for the establishment of an effective image processing system: the number of analyst who will have access to the system at one time; the mode of operation, the central processing unit (CPU); the operating system; types of compilers; the amount and types of storage required; the spatial and colour resolution desired; an the image processing software.

3. Digital Image Processing Procedures

3.1 Pre-Processing

Prior to actual analyzing of the remotely sensed data, it is usually necessary to preprocess it (Teillet, 1986). This is mainly due to some errors that have been crept into data acquisition process. These errors have found to be degrading the quality of remote sensing data. The most common errors found in remotely sensed imagery are radiometric and geometric errors and the process of image rectification and restoration can correct these errors. These processes are normally known as preprocessing operation because they are often carried out before further manipulation and analysis of the image data to extract specific information.

3.2 Radiometric correction

Various factors that have contributed to radiometric errors in remotely sensed data are;

1. The sensor system itself that is when the individual detectors do not function properly or are improperly calibrated (Teillet, 1986).
2. The intervening atmosphere between the terrain of interest and the remote sensing system.

Correction of Errors due to Environmental Attenuation

Lillesand and Keifer (2000), describe factors such as changes in scene illumination, atmospheric conditions, viewing geometry, and instrument response characteristic as among some of the important factors that have affected the amount of radiant flux recorded by remote sensing system. It is therefore very important to find out how all such error may be removed from the remotely data before they are further analysed.

To understand how to remove the error (noise) introduced by the atmosphere into remotely sensed data, it is necessary to understand some fundamental radiometric concepts (Forster, 1984).

In an ideal situation, the radiant energy recorded by the detectors is an absolute function of the amount radiant flux leaving the instantaneous field of view (IFOV) under investigation. However, other radiant energy enters into the field of view from various other paths. Various path of radiance received by the remote sensor detector is shown in Figure 2

Path 1: Only very little amount of EMR from the Sun was attenuated before illuminating the terrain within the IFOV.

Path 2: EMR that may never reach the Earth's surface because of scattering in the atmosphere. Unfortunately, such energy is often scattered into the FOV of the sensor system.

Path 3: Contains energy from the Sun that has undergone some Rayleigh, Mie, and/or Non-selective scattering and perhaps some absorption and re-emission before illuminating the study area. Thus, its spectral composition and polarization may be somewhat different than the energy in Path 1.

Path 4: Radiation that was reflected or scattered by nearby terrain such as snow, concrete, soil, water, and/or vegetation into the IFOV of the sensor system. The energy does not actually illuminate the study area.

Path 5: Energy that was reflected from nearby terrain into the atmosphere and then scattered or reflected onto the study area.

The total radiance reaching the sensor can be calculated using Equation 1 as follows;

$$L_S = \frac{1}{\pi} R \times T_{\theta_v}\left(E_{o\Delta\lambda} T_{\theta_o} \cos\theta_o \Delta\lambda + E_d\right) + L_p \qquad \ldots\ldots\ldots\ldots\ldots \quad 1$$

The atmospheric correction attempts to minimize or removed the contribution of *Path Radiance, Lp.*

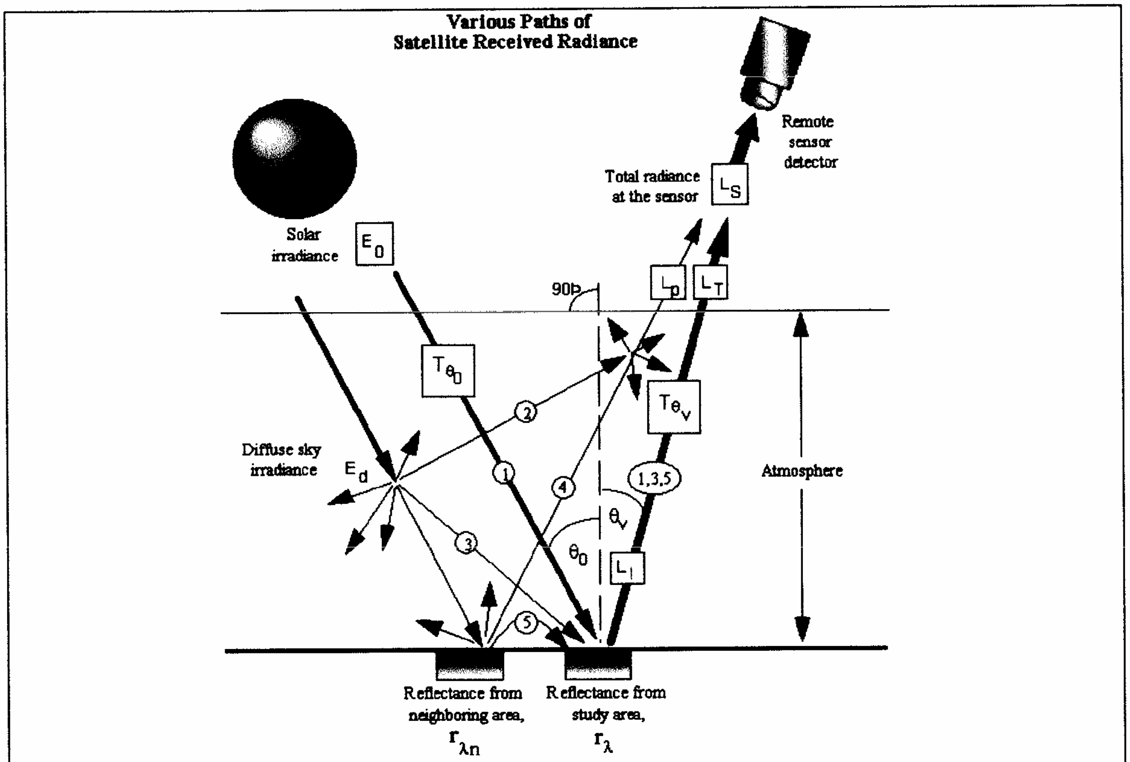

Figure 1 Various path of radiant received by satellite remote sensing system

Source: Jensen, 1996

Correction of Error Due to Sensor System Detector Error

Common radiometric errors include resulted from the remote sensing system that does not function properly are line *drop-outs*, *striping* or *banding*, and *line-start* problems.

Line drop-outs problems can be corrected using Equation 2 which is performed for every pixel in a bad scan line

$$BV_{ijk} = Int\left(\frac{BV_{i-1,j,k} + BV_{i+1,j,k}}{2}\right) \qquad \text{.................................... 2}$$

3.3 Geometric Correction

Geometric distortion is an error on an image, between the actual image coordinates and the ideal image coordinates, which would be projected theoretically with an ideal sensor and under ideal conditions.

Geometric distortions are classified into **internal distortion** resulting from the geometry of the sensor, and **external distortions** resulting from the attitude of the sensor or the shape of the object.

Geometric correction is undertaken to avoid geometric distortions from a distorted image, and is achieved by establishing the relationship between the image coordinate system and the geographic coordinate system using calibration data of the sensor, measured data of position and attitude, ground control points, atmospheric condition etc.

There are two basic types of geometric correction:

3.3.1 Image-to-image registration

This is useful for registering two or more images together when it is not necessary to have the interpreted output in a formal map projection. Image-to-image registration may also be used to perform simple non-quantitative change detection.

3.3.2 Image-to-map rectification

This is useful when preparing images and interpreted output for presentation in a rigorous map projection using a known geoid and datum. This technique is very important when performing digital change detection.

3.4 Image Enhancement

Image enhancement algorithms are applied to remotely sensed data to improve the appearance of an image for human visual analysis or occasionally for machine analysis.

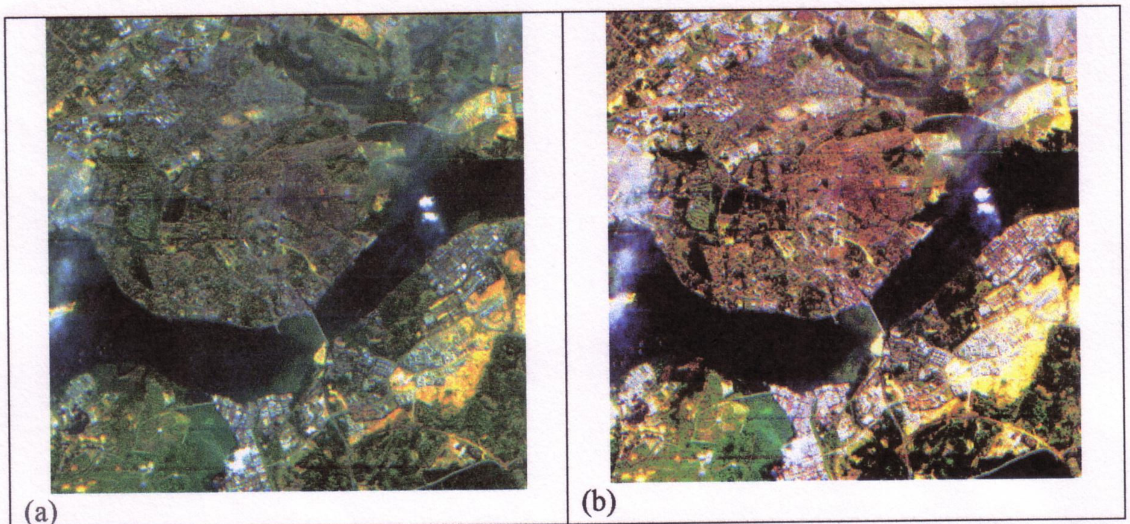

Figure 2 (a) An example of image before enhancement, and (b) Example of Image after enhancement

Figure 2a, is an example of an original image before enhancement. A bluish tint can be seen all-over the image, producing a hazy appearance. This hazy appearance is due to scattering of sunlight by atmosphere into the field of view of the sensor. This effect seems to degrade the contrast between different land covers. The quality of visual appearance of image after enhancement as shown in Figure 2b is much better.

3.4 Image Classification

Image classification is carried out to automatically categorize all pixels in an image into land cover classes or theme. Different land cover types in an image can be discriminated using some image classification algorithms using spectral features, i.e. the brightness and "color" information contained in each pixel. The classification procedures can be "supervised" or "unsupervised".

3.4.1 Supervised Classification

In supervised classification, the spectral features of some areas of known land cover types are extracted from the image. These areas are known as the "training areas". Every pixel in the whole image is then classified as belonging to one of the classes depending on how close its spectral features are to the spectral features of the training areas.

3.4.2 Unsupervised Classification

In unsupervised classification, the computer program automatically groups the pixels in the image into separate clusters, depending on their spectral features. Each cluster will then be assigned a land cover type by the analyst.

In many cases, classification will be undertaken using a computer, with the use of mathematical classification techniques. Classification will be made according to the following procedures.

Step 1: Definition of Classification Classes

Classes should be clearly defined based on the objective and the characteristics of the image data.

Step 2: Selection of Features

Features to discriminate between the classes should be established using multi-spectral and/or multi-temporal characteristics, textures etc.

Step 3: Sampling of Training Data

Training data should be sampled in order to determine appropriate decision rules. Classification techniques such as supervised or unsupervised learning will then be selected on the basis of the training data sets.

Step 4: Estimation of Universal Statistics

Various classification techniques will be compared with the training data, so that an appropriate decision rule is selected for subsequent classification.

Step 5: Classification

Depending on the decision rule, all pixels are classified in a single class. There are two methods of pixel by pixel classification and per-field classification, with respect to segmented areas.

Popular techniques of classification are as follows.
a. Multi-level slice classifier
b. Minimum distance classifier
c. Maximum likelihood classifier
d. Other classifiers such as fuzzy set theory and expert systems

5. Overview of Remote Sensing Applications in Malaysia

In Malaysia remote sensing technology and applications development has been spearheaded by the National Remote Sensing Committee (NRSC) since its formation in 1977 under the Economic Planning Unit, Prime Minister's Department. The role of